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Enhancing Energy Security through Utilization of Local Resources
Case Study: Biomass/Biogas Utilization in Berau Regency, East Kalimantan

Indradarma Adiwibowo[1]*, Dita Anggun Lestari[2], Davit Manalu[3]

[1]*Patriot Negeri, Basecamp Patriot Negeri Gang Bina Karya, Jl.H.A.RM Ayoeb, Teluk Bayur, Berau, East Kaimantan, Indonesia 77313*

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Abstract. Remote rural villages in Indonesia do not have sufficient infrastructure to maintain an economically sound energy generation and distribution. Sparse area and low population hinder national electricity company PLN (Perusahaan Listrik Negara) to connect these remote rural villages to the national grid. Most of the villages lie in the palm oil plantation, where renewable biomass resources from the Palm Oil Mill wastes are plentiful. Untapped biomass resources could be the answer to energy security issue in the remote rural area. Berau Regency in East Kalimantan Province has many villages located in the palm oil plantation area. Nearly all of the palm oil processing plants in Berau use palm shell and fiber to power the mill. Some of them have the agreement with PLN to sell their excess power. This scheme can be applied to provide electricity to villages around the palm oil mills. However, it is unreliable since the amount of excess electricity produced keeps fluctuating. This paper explores the idea of village-owned biomass/biogas power plant that is owned and operated by the villagers themselves. That way, the village can ensure its energy security using sustainable local resources. In conclusion, the investment cost of biomass/biogas power plant cannot be provided by village annual budget. Although the villages in Berau Regency have a relatively high annual budget, wich is about Rp2 billion to Rp5 billion, the investment costs of biomass/biogas power plant is even higher. According to the economic analysis of biomass/biogas power plant development, a biomass power plant with 1,7 MW capacity can cost up to Rp46 billion. Moreover, a biogas power plant with 1 MW capacity costs around 41 billion. It is not possible for the villages to finance the power plant development by themselves. Therefore, the private sector is needed to implement biomass/biogas utilization for rural electrification from palm oil waste. With the Net Present Value (NPV) up to Rp 65.078.072.000,00 and Internal Rate of Return (IRR) of 20% for biomass power plant and Rp14.330.070.000,00 and 10% for biogas power plant, it is economically feasible and profitable for private enterprise to undertake. The challenges are for the government to encourage the private sector to invest and for PLN to sign Power Purchase Agreement with these palm oil enterprises rather than just Excess Power Agreement.

JEL Classification: I39
Keywords: Biomass, biogas, renewable energy, palm oil waste utilization

1. Introduction

There are many villages in Berau Regency that can be considered remote and do not have access to basic infrastructures, such as electricity. Those villages are far enough from the main grid of national electricity company or Perusahaan Listrik Negara (PLN) that connecting those villages to the main grid is not economically feasible. Many of these villages are located near palm plantation area. The palm oil is then processed locally in private Palm Oil Mills (POM) which produce both solid and liquid waste. Solid waste can be used as fuel to produce energy both heat and electricity. On the other hand, liquid

* Corresponding author
E-mail address: patriotnegeriberau@gmail.com

waste, generally called Palm Oil Mill Effluent (POME), can be processed to produce biogas which in turn also produce energy. Exploring the possibility of utilizing these biomass/biogases from POM waste could be the answer to energy security issue in the remote rural area.

Berau regency has palm plantation area about 120.535 Ha that produces palm fruit of 1.221.143 tonnes, whereas forest area is about 2.188.262,59 Ha (East Borneo Plantation Agency, 2017). This data can explain how huge biomass resources that could be exploited. There are 7 POMs in Berau. Two of them which is operated in Talisayan and Segah Sub-district, already use their waste as energy sources to power the mill and the worker camps. PT. X operates in Talisayan Sub-district and they operate Biomass combustion power plant fuelled by the solid waste from the mill itself. The mill operated by PT. Y in Segah Sub-district is powered by the same biomass combustion power plant. In addition, it also utilizes biogas power plant to power the mill. Both companies already have an agreement with PLN to sell their excess power to PLN. PLN then distributes the electricity to nearby villages. This scheme allows neighboring villages to have access to electricity produced from POM.

This scheme has a downside that whenever the POM needs extra power, the amount of electricity sold to PLN would decrease and resulting blackout in the villages. This case happens very often, means that the villages still do not have a reliable electricity source. This hampers economic development of the villages as the people still dependent on the palm oil company excess power for electricity.

If the villages can own and operate the power plant themselves, they can achieve energy security by having a reliable electricity generation facility. The purpose of this research is to explore the feasibility of village-scale biomass plant to be owned and operated by the village.

2. Methodology

Literature study is the first step of the research, followed by a site visit to two palm oil mill in Berau Regency, PT. X in Talisayan Sub-district and PT. Y in Segah Sub-district.

The site visit provides the necessary data about the investment and operational requirement of construction and running a biomass/biogas power plant, such as:

1. Initial investment
2. Operational Cost
3. Technological level
4. Human resource requirement

These data is then compared to village data acquired by the authors were to assess the feasibility of a village-owned biomass/biogas power plant. By using the cash flow analysis, we can calculate the economic feasibility.

In this paper, we limit our research to only two systems. We only analyzed combustion cycle technology for biomass power plant and Continuously-Stirred Tank Reactor (CSTR) for biogas power plant. The research was conducted in villages in Berau Regency, East Kalimantan.

3. The Technology

a. Biomass Power Plant System

Biomass power is carbon neutral electricity generated from renewable organic waste that would otherwise be dumped in landfills, burned, or left as fodder for forest fires such as palm oil waste (fiber and shell), wood and animal waste. Biomass resources can be continuously produced which creates sustainable energy resources (LLC, 2011).

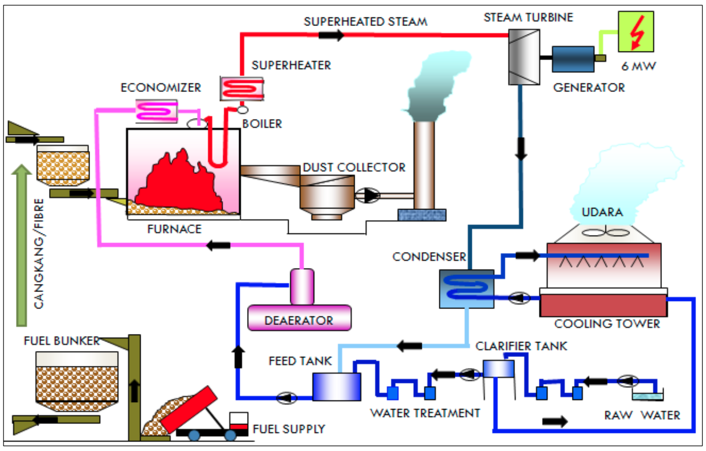

Figure 1. Biomass Power Plant System in Palm Oil Mill (Erhaneli, 2017)

There are two types of biomass power plant energy production system. The first system is direct combustion of solid biomass in boiler and second system is gasification which produces methane that is used as fuel.

Table 1. Calorific Value of Biomass (Peter Quaak, 1999)

Type	***LHVw (kJ/kg)***	***MCw(%)***	***ACd(%)***
Bagasse	7.700-8,000	40-60	1,7-3,8
Cocoa husks	13.000-16.000	7-9	7-14
Coconut shells	18.000	8	4
Coffee husks	16.000	10	0.6
Cotton *residues*			
Stalks	16.000	10-20	0,1
Gin trash	14.000	9	12
Maize			
Cobs	13.000-15.000	10-20	2
Stalks			3-7
Palm Oil Residues			
Fruit stems	5.000	63	5
Fibers	11.000	40	
Shells	15.000	15	
Debris	15.000	15	
Peat	9.000-15.000	13-15	1-20
Rice husks	14.000	9	19
Straw	12.000	10	4.4
Wood	8.400-17.000	10-60	0,25-1,7
Charcoal	25.000-32.000	1-10	0,5-6

Combustion system types commonly used which energy comes from combusting shells and fibers to power the turbine. Fuel is stored in a bunker for further transport to the boiler. In the boiler, water is heated to high temperature under pressure. The steam temperature can reach up to 550ºC. Steam from the boiler rotates power the turbine, which is connected to the generator. Steam that has passed through the turbine then sent to the condenser and then to cooling towers where it cooled down before going back to boiler again.

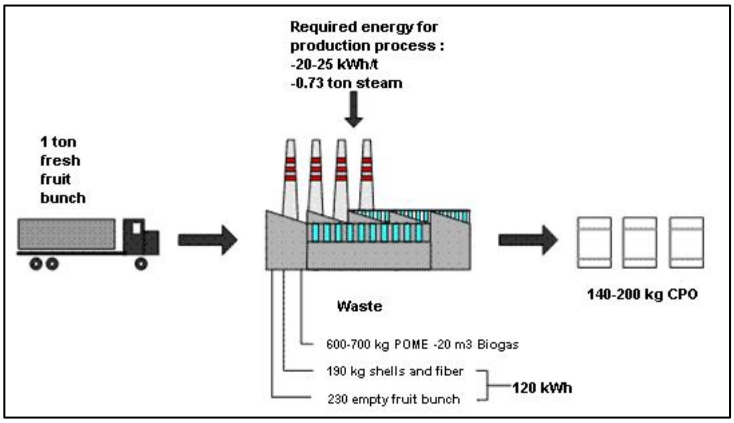

Figure 2. Material Balance of Power Plant in Palm Oil Mill (Wibowo, 2016)

b. Biogas Power Plant System

Biogas power plant uses methane produced from POME as fuel. Biogas is a product of anaerobic activity or fermentation from organic matter such as animal waste, liquid organic waste or any organic waste which are degradable in anaerobic condition. The primary contents of biogas are methane and carbon dioxide. In the power plant system, methane combustion converts chemical energy to kinetic energy which powers generator.

Biogas production has four separate stages (USAID, 2015)

1. Hydrolysis: Hydrolysis is a reaction to water. Acid and base can be used to accelerate the reaction. The organic substrate contains a different proportion of cholesterol, protein, and carbohydrate can be hydrolyzed into dimer and polymers (fatty acid, amino acid, and sugar).
2. Acidogenesis: Conversion of pimer and polymers by bacteria into organic acid or volatile fatty acid.
3. Acetogenesis: alcohol and fatty acid turn into acetic acid, CO_2 and H_2.
4. Methanogenesis: The process of methanogens producing methane.

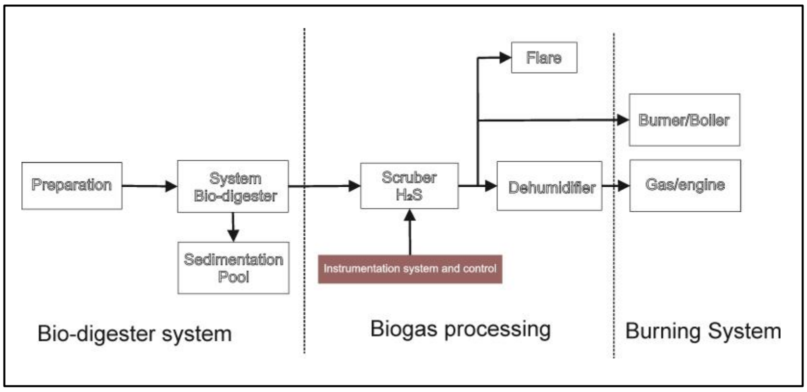

Figure 3. Biogas Power Plant Diagram (USAID, 2015)

4. Regulation

The Ministry of Energy and Mineral Resources Regulation Number 50/2017 about utilization of renewable energy for electricity supply section 8 and 9 explains the mechanism for purchasing power produced by biomass and biogas power plant that has a capacity up to 10 MW. In terms of generic cost of generation or *Biaya Pokok Pembangkitan* (BPP), the electricity produced by Biomass and Biogas power plant can be purchased by PLN to a maximum of 85% from regional BPP.

While the BPP itself is regulated in Ministerial Decree No. 1404 K/20/MEM/2017, It is stated that regional BPP in East Borneo is about Rp1.357,00/kWh. As a result, the price of is Rp1.153/kWh of maximum purchasing price from Independent Power Producer (IPP).

These regulations were use as the references for paper analysis for the economic feasibility of biomass/biogas power plant village scale development. In excess power agreement, the company use BPP in East Borneo. Energy price according to current agreement between PT. X and PT. Y as IPP and PLN is Rp1.150,00/kWh each.

Ministry of Energy and Mineral Resources Regulation Number 38/2016 on accelerating electrification in undeveloped rural areas, remote regions, border areas, and small inhabited islands through the implementation of small-scale electricity provision enterprises encourage the private sector to invest on power plant development below 50 MW capacity. To support the development of renewable energy power plant especially biomass/biogas we can relate this regulation to develop and doing acceleration for renewable energy growth in Indonesia. This regulation can support the development of biomass/biogas power plant and encourage the private sector to build it.

5. Study Case in Berau

a. PT. X, Talisayan Sub-district

Palm Oil Mill (POM) of PT. X in Talisayan Sub-district have a processing capacity of 60 tonnes/hour which operates in 12 hours resulting in 720 tonnes/day capacity. This mill receives up to 1.000 tonnes of Fresh Fruit Bunch (FFB) a day. To power this mill, there is a power plant with installed capacity of 2 X 1,7 MW which one generator is acting as a backup. With 85% plant efficiency, the net power generated is about 1,5 MW. Roughly 1,2 MW of power generated is for internal use while 0,3 MW excess is purchased by PLN with Feed-In Tariff of Rp1.150/kWh. This excess power purchase agreement has been in place since July 2013.

Based on PT. X data in June 2017, POM waste can be categorized as dirt 8,93%, empty bunch 25%, sludge 17,16%, shell 4,10% and fiber 4,74%.The waste ratio is 60% of total 11.200 tonnes of FFB. Therefore, about 23,1 tonnes/day of fiber and shell is fed to the biomass power plant with capacity of a 1,5 MW.

Figure 4. Power Generator Name Plate

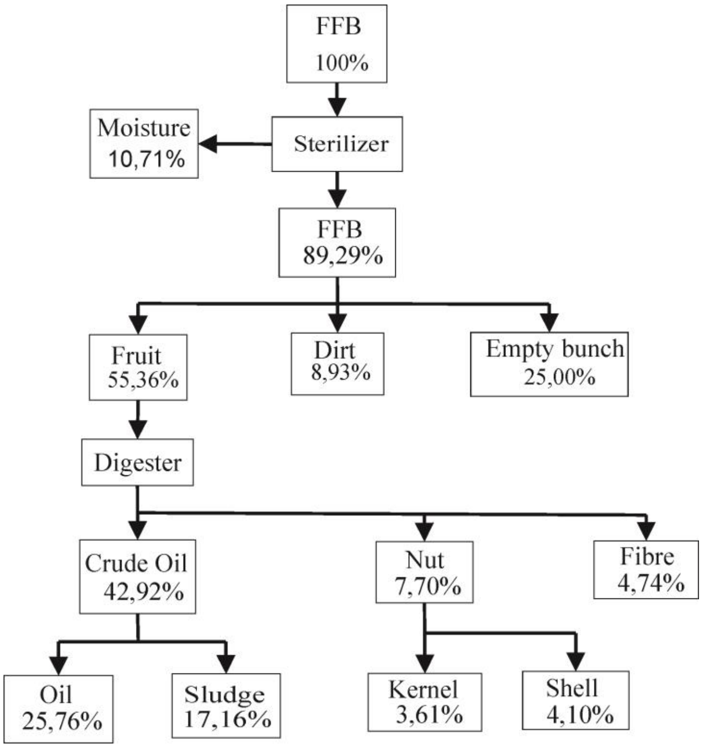

Figure 5. Material Balance of PT. X

Based on production data in 2017, the average power plant energy production was about 311,147 kWh/month, and an auxiliary diesel generator produced 64,804 kWh/month. The total energy produced was then divided into internal use, and excess power which 301,187 kWh was allocated for internal use and 74,764 kWh was excess power purchased by PLN to power villages around PT. X mill.

As a consequence, average income generated from this excess power agreement per month was Rp85.978.600,00

PT. Y, Segah Sub-district

PT.Y POM in Segah Sub-district has a processing capacity of 120 tonnes/hour, but now is operating with a capacity of 90 tonnes/hour. This mill receives up to 40.000 tonnes of FFB per month or about 1.333 tonnes/day. Fuel consumption for diesel generator is 5.000 L/month. Installed biogas power plant 1 MW capacity produces effective power about 799 kW. If needed, the company could upgrade the biogas power plant to 2 MW. Power purchase agreement was established in October 2015, started with biomass power plant and then biogas power plant installed in December 2016. In this company, biogas power plant has its own management that is separated from palm oil mill management.

With FFB supply of 40.000 tonnes/month and 30% yield, 28.000 tonnes of waste can result in 11.913 m^3 of Palm Oil Mill Effluent (POME) per month. That amount of POME can produce 366.681 m^3 of biogas with a ration of 30,77 m^3 biogas per 1 m^3 POME.

Based on production data since December 2016, an average of effective energy production was 374.912 kWh. Energy allocation in a month is divided to supply employee housing of 102.613 kWh, palm oil mill of 182.047 kWh, and excess power purchased by PLN of 89.252 kWh with a Feed-in tariff of Rp1.150,00/kWh. Hence, the Average income generated from this excess power agreement in a month was Rp102.639.800,00.

6. Technology Analysis

Technology analysis has the purpose of evaluating the possibilities of village-owned biomass/biogas power plant. By comparing it with another renewable energy that has been implemented in a rural remote area like micro-hydro power or communal solar power plant and assessing any aspects that can assure the sustainability of the project such as production process, power plant maintenance, human resources, and environmental study.

a. Production Process

One tonne of FFB can produce 200 kg crude palm oil (CPO), 190 kg of shells and fiber and 230 kg of the empty bunch. Combustion from shells, fibre, and empty bunch which weight about 420 kg can produce ± 120 kWh. The production process uses a steam turbine that should be monitored periodically.

To produce one tonne of FFB in Indonesia need 900 m^2 plantation area which can produce 120 kWh, whereas solar power plant needs 900 m^2 area to produce 16 kWh. But solar power plant is much cleaner than biomass power plant because solar power plant does not produce any waste during its operation. Where in contrast, biomass power plant produces combustion waste, noise, and air pollution.

b. Spare Parts Availability

Biomass and biogas production need generator which is imported from countries like Japan, UK, and USA. Spare parts like deaerator, HP/LP heater, Condenser, Gland Heater, Water filter, Oil Filter, Steam Filter, Oil Cooler, Extraction Valve, Oil Tank, Ejector, 2 stage steam jet air ejector, safety valve imported to from that countries. This case is the same as solar power plant wich spare parts were imported from other countries like Germany, China, and Canada.

c. Human Resources Needed

Human resources quality can impact the sustainability of biomass power plant. Biomass power plant needs daily maintenance and constant monitoring when the plant is active. The nature of combustion process that requires high temperature and pressure makes it a high-risk job. That is why, biomass power plant needs a group highly skilled and experienced worker, working cooperatively to operate the plant. While solar and micro-hydro power plant does not require intense monitoring and only need one person as an operator at a time.

d. Village-owned Biomass/Biogas Power plant, technological point of view

Disadvantages:
1. Require a group of skilled operator that should be monitoring boiler condition, etc.
2. Require constant monitoring.
3. Ignition takes time too long.
4. Need huge amount of water.

Advantages:
1. Reducing palm oil waste.
2. Reducing fossil fuel consumption.
3. Renewable resources.
4. Local raw materials.

7. Economic Analysis

a. Existing Condition Material Balance

We analyze the material balance of both biomass and biogas power plant from PT. X and PT. Y respectively to find if there is still enough biomass supply if we want to develop a biomass/biogas power plant.

From the data, we gather from field study we can calculate the amount of biomass needed to supply current electricity generation process as presented in the table below.

Table 2. Material Balance of Biomass Power Plant

Current Electricity Generation	311.147	kWh
Fuel Consumption Rate	0,932330827	kg/kWh
Total Fuel Consumption	290.091,94	kg
Biomass Requirement	290,09	ton
Biomass Supply	1.286	ton
Biomass Surplus	995,91	ton

Table 3. Material Balance of Biogas Power Plant

Current Electricity Generation	374.912	kWh
Fuel Consumption Rate	0,600	m^3/kWh
Total Fuel Consumption	224.947,20	m^3 biogas
POME/Biogas Ratio	30,73	
POME Requirement	7.320,12	m^3 POME
POME Supply	11.913	m^3 POME
POME Surplus	4.592,88	m^3 POME

From both tables, we can conclude that there are still rooms for development of biomass power plant. From PT.X, there is a surplus of 402,91 tonnes of palm oil wastes. Meanwhile, from PT.Y, there is a surplus of 4.592,88 m^3 of POME. Both can be used to further optimize power generation from each power plant.

b. Development Plan

We analyze both biomass and biogas power plant from PT. X and PT. Y respectively regarding of Net Present Value (NPV), Internal Rate of Return (IRR) and Payback Period (PBP). We also calculate the energy production cost of each power plant.

Each analysis is divided into two scenarios. In the scenario I, the use of electricity still takes account consumption of the mill itself and other self-consumption, as such the amount of electricity sold to off-taker (PLN) will be decreased. While in scenario II, all the power generated will be sold to the off-taker.

Moreover, each scenario is then divided into two sub-scenarios. Sub-scenario A assume the plant is built in conjunction with Palm Oil Mill, so the fuel is supplied from the mill, therefore, eliminating the fuel cost. In sub-scenario B, the power plant is built independently, so it needs to provide the fuel from elsewhere, adding a fuel cost.

Key assumptions for the calculation are
- Project lifetime : 20 years
- Capacity Factor : 85%
- Parasitic Load : 6%
- Discount Rate : 6%
- Feed-In Tariff : Rp1.150/kWh

c. PT. X Biomass Power Plant

After we analyze the material balance of PT.X Mill, we know that there is a supply of 1.286 tonnes of solid waste that can be used for electricity generation. The PT. X Biomass Plant specifications are:

- Installed Capacity : 2.300 kW
- Operating Capacity : 1.700 kW
- Capacity Factor : 85%
- Parasitic Load : 6%
- Plant Heat Rate : 3.100 kcal/kWh
- Fuel Caloric Value : 3.325 kcal/kg
- Fuel Consumption : 0,9 kg/kWh

For this analysis, it is assumed that the plant works on full operating capacity which is 1.700 kW. Energy generated from this capacity is 977.976 kWh/month. By calculating the fuel consumed for each kWh, it turns out that the amount of fuel needed is 911,8 tonnes. This demand can be fulfilled by the supply from PT.X mill.
The amount of self-consumption for the scenarion I is 263.383 kWh/month for PT.X mill and employee housing. So the amount of energy that can be sold is only 741.593 kWh/month. In scenario II, all of the energy produced will be sold to off-taker.

Table 4. Energy Production of PT. X

Scenario	Energy Produced (kWh/month)	Energy Sold (kWh/month)	Fuel Price (Rp/kg)
IA	977.976	741.593	Rp0
IB	977.976	741.593	Rp400,00
IIA	977.976	977.976	Rp0
IIB	977.976	977.976	Rp400,00

From literature study, the total investment cost of Biomass Power plant is Rp46.780.000.000,00. The cost can be broken down into several items:
- Feasibility study & planning : Rp30.000.000,00
- Engineering : Rp935.000.000,00
- Equipment & Material : Rp39.950.000.000,00
- Civil works : Rp2.295.000.000,00
- Buildings : Rp1.275.000.000,00
- Contingency : Rp2.295.000.000,00

Meanwhile, the operational cost can be divided into three components:
- Salary and Labour : Rp548.049,25/kW
- Operation & Maintenance : Rp480.421,99/kW
- Variable Cost : Rp29,76/kWh

Fuel price is unfortunately very speculative as there is no market for POM solid waste in Berau at the moment. Authors use literature study and peer interview to approximate the price of fuel.

All of the economic feasibility parameter is tabulated in the table below.

Table 5. Economy Analysis for Energy Production of PT.X

Scenario	NPV (in million rupiahs)	IRR (%)	PBP (year)	Production Cost (Rp/kWh)
IA	Rp27.662,86	13%	7,21	Rp785,62
IB	-Rp22.536,70	-1%	22,13	Rp1.158,56
IIA	Rp65.078,72	20%	4,80	Rp785,62
IIB	Rp14.879,16	10%	8,70	Rp.158,56

From the table, we can conclude that the most feasible scenario is scenario IIA where NPV can reach Rp65.078.720.000,00, IRR 20% and a payback period of 4,8 years. Scenario IA and IIB can also be considered feasible as all of the economic parameters fulfill the requirement of a profitable project. The only scenario that is considered not feasible is scenario IB.
It is reasonable that scenario IIA is the most feasible option, because it utilizes the full capacity of the plant, whereas scenario IB only utilizes a portion of it. So the revenue generated is lower compared to the investment cost and subsequent operating and maintenance cost. In addition, scenario IB also has to add the cost of fuel purchase that further hamper its feasibility.

Concerning the production cost, scenario I have a significantly lower production cost than scenario II. This emphasizes the significance of fuel cost in the production cycle. Scenario I have a production cost of Rp785,62 while scenario II is Rp1.158,56. Only scenario I have a production cost that is lower than the feed-in tariff.

d. PT. Y Biogas Power plant

While PT.X power plant serves as an example for assessing the biomass power plant, PT.Y having operated biogas power plant will be the ground for assessing the possibility of village-owned biogas power plant.

From earlier material balance analysis, we know that PT.Y mill can produce up to 11.913 m3 of POME every month.

- Installed Capacity : 1.000 kW
- Capacity Factor : 85%
- Parasitic Load : 6%
- POME/Biogas Ratio : 30,73
- Fuel Consumption : 0,9 m^3/kWh

For this analysis, it is assumed that the plant works on full operating capacity which is 1.000 kW. Energy generated from this capacity is 575.280 kWh/month. By calculating the fuel consumed for each kWh, it turns out that the amount of fuel needed is 11.232,28 m3 of POME. This demand can be fulfilled by the supply from PT.Y mill.

The amount of self-consumption for scenario I is 285.660 kWh/month for PT.Y mill and employee housing. So the amount of energy that can be sold is only 289.620 kWh/month. In scenario II, all of the energy produced will be sold to off-taker.

Table 6. Energy Production of PT.Y

Scenario	Energy Produced (kWh/month)	Energy Sold (kWh/month)	Fuel Price (Rp/m3)
IA	575.280	289.620	Rp -
IB	575.280	289.620	Rp200,00
IIA	575.280	575.280	Rp-
IIB	575.280	575.280	Rp200,00

The total investment cost of biogas plant is lower than biomass plant. For 1 MW of capacity, biogas plant cost about Rp41.530.000.000,00 that can be broken down into components:

- Feasibility study & planning : Rp30.000.000,00
- Engineering : Rp3.000.000.000,00
- Equipment & Material : Rp25.000.000.000,00
- Civil works : Rp3.000.000.000,00
- Buildings : Rp6.750.000.000,00
- Contingency : Rp3.750.000.000,00

Operational Cost:
- Salary and Labour : Rp548.049,25/kW
- Operation & Maintenance : Rp1.250.000,00/kW
- Variable Cost : Rp55,34/kWh

In the same case with biomass fuel, biogas fuel (i.e., POME) is not readily available in Berau market nor in any market that the authors have researched. So, the authors have to speculate by approximating a possible price for POME.

In the case of biogas power plant, the feasible scenarios are scenario IIA and IIB. But, between scenario IIA and IIB, the difference on profitability is not high. This is because the low cost of fuel as POME is considered very efficient on producing biogas.
Scenario IA and IB do not comply with the feasibility requirement as their NPV and IRR are negative. This is due to too much of the energy generated is used for self-consumption within the palm plantation area.

Table 7. Economy Analysis for Energy Production of PT.Y

Scenario	NPV (in million rupiahs)	IRR (%)	PBP (year)	Production Cost (Rp/kWh)
IA	-Rp30.884,96	-7%	44,75	Rp1.224,56
IB	-Rp31.194,16	-7%	46,09	Rp1.228,46
IIA	Rp14.330,70	10%	8,53	Rp1.224,56
IIB	Rp14.021,50	10%	8,57	Rp1.228,46

It should be noted that the production cost per kWh of all scenario is still higher than the feed-in tariff of electricity, even for scenario II. The lowest production cost is Rp1.224,56 while the highest is Rp1.228,46.

e. Economic Feasibility of Village-Owned Biomass/Biogas Power plant

From an economical point of view, Biomass/Biogas Power plant fuelled by palm oil industry waste need a considerable amount of capital investment. In our case study in PT.X that utilize solid waste of palm tree and PT.Y that uses POME, needs about Rp46.780.000.000,00 and Rp41.530.000.000,00 of capital investment respectively.

Compared to the financial ability of villages in Berau as shown in the table. On average, each village in Berau have a budget of Rp2.914.733.333,33 per year that it can spend on various activities. One of the activity is infrastructure development, such as electricity generation plant and distribution.

Even if the village decided to spend all of their budgets on building the biomass/biogas power plant, it needs up to 14 to 16 villages to pool their budget build one, which is an unlikely scenario. External financing would be difficult to get, as the village did not have enough collateral to propose funding from banks or other financial bodies.

Table 8. Village Financial Allocation

No	Item	Village Name		
		Merancang Ilir	Punan Malinau	Tabalar Muara
1	Village Allocation Fund	Rp2.086.263.000,00	Rp2.036.459.000,00	Rp2.000.258.000,00
2	Village Fund from State Budget	Rp816.322.000,00	Rp823.955.000,00	Rp801.559.000,00
3	Taxes	Rp41.668.000,00	Rp37.875.000,00	Rp38.551.000,00
4	Regional Government Aid	Rp15.000.000,00	Rp15.000.000,00	Rp15.000.000,00
5	Additional Funding	Rp92.845.914,00	Rp91.691.692,00	Rp51.044.300,00
Total Income		Rp2.959.253.000,00	Rp2.919.479.000,00	Rp2.865.588.000,00

8. Conclusions and Recommendations

a. Conclusions

1. Current operation of PT. X biomass plant and PT.Y biogas plant still have enough surpluses of biomass/biogas fuel to expand its electricity generation.
2. For both biomass and biogas plant, the most feasible and profitable scenario is IIA, where the power plant is built within a Palm Oil Mill so that there would be no added fuel cost.
   a. In case of biomass power plant, the NPV can reach Rp65.072.788.846,18; IRR of 20%, with a payback period of 4,8 years.
   b. In case of biogas power plant, the NPV can reach Rp14.330.703.764,86; IRR of 10%, and payback period of 8,5 years.
3. In terms of production cost, only biomass power plant that can achieve production cost lower than the feed-in tariffs of Rp1.150/kWh. The biomass power plant from scenario I have a nominal production cost of Rp785,62/kWh, while biogas power plant production cost reaches Rp1.224,56/kWh.
4. Village-owned biomass/biogas plant that utilizes Palm Oil Mill wastes is not possible due to several points :
   a. Operating a biomass/biogas power plant needs a group of skilled and experienced workers
   b. Village does not have a financial capacity to construct a biomass/biogas power plant

b. Recommendations

1. Private enterprise should be encouraged to invest in biomass/biogas power plant and sign a Power Purchase Agreement with PLN rather than Excess Power Agreement.
2. The government can attract more investment from the private sector by increasing the feed-in tariff.
3. Further studies should be conducted on other types of renewable energy power plant that can realistically be built in the rural area and operated by local people.

References

Buku Panduan Konversi POME menjadi Biogas Pengembangan Proyek di Indonesia. (2015). Jakarta: USAID.

Buku Pedoman Energi Bersih untuk Lembaga Jasa Keuangan. (2014). Jakarta: Otoritas Jasa Keuangan.

Erhaneli, E. A. (2017). Pemanfaatan Cangkang dan Serabut Sawit sebagai Bahan Bakar Pada PLTU untuk Memenuhi Kebutuhan Listrik Masyarakat Kabupaten Bungo. *Jurnal Momentum*, 10-18.

LLC, R. H. (2011). ReEnergy Holdings LLC. Retrieved from ReEnergy Holdings LLC: https://www.reenergyholdings.com/renewable-energy/what-is-biomass/

Pembiayaan Pembangkit Listrik Tenaga Biogas. (2016). Jakarta: Otoritas Jasa Keuangan.

Peter Quaak, H. K. (1999). *Energy from Biomass A Review of Combustion and Gasification Technologies.* Netherlands: World Bank.

Wibowo, A. (2016). Perancangan Sistem Pembangkit Listrik Biomassa Sawit (PLTBS) Kapasitas 5kW. *Jurnal Mekanika dan Sistem Termal,* 53-60.